Planned Improvements to REMUS, a VSW MCM Semi-Autonomous Hydrographic Reconnaissance Vehicle System

Christopher von Alt and Thomas Austin
Oceanographic Systems Laboratory
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
phone: (508) 289-2290 fax: (508) 457-2104 e-mail: cvonalt@whoi.edu
phone: (508) 289-2894 fax: (508) 457-2104 e-mail: taustin@whoi.edu
Award #: N00014-99-1-0280
http://adcp.whoi.edu

LONG-TERM GOALS

Current naval operational instructions task Navy Special Warfare forces (NSW) with the responsibility to conduct hydrographic and mine field reconnaissance missions in very shallow water (3-12 m) in forward areas throughout the world. NSW forces are required to map and monitor the extent of the sea mine threat and to identify the locations and extent of any gaps within a minefield. A successful mission requires clandestine or covert insertion, surface and subsurface reconnaissance, clandestine/covert extraction, and the production of a survey chart, that provides the Task Force Commander with the positions of identified mines, the coordinates of any mine field gaps, and the bathymetry of the mined region. This information must be available immediately, and in a suitable electronic format for transmission via a satellite communication link. Small autonomous vehicles provide a realistic tool for accomplishing this mission.

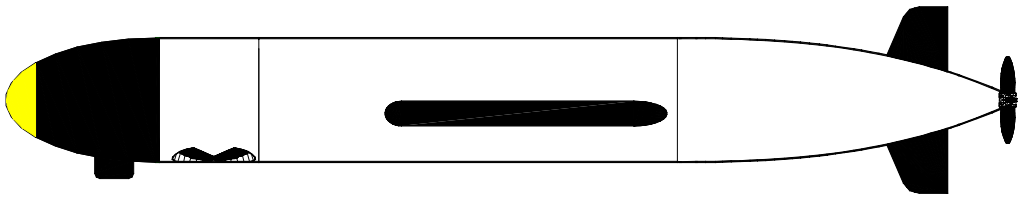

Figure 1 Semi-Autonomous Hydrographic Reconnaissance Vehicle

OBJECTIVES

Robust and practical Autonomous Underwater Vehicle (AUV) operations will provide the Navy with an alternative to traditional diver based minefield and hydrographic reconnaissance techniques. The overall objective of this work is to develop improved methodologies of performing covert coastal surveillance and reconnaissance in littoral regions throughout the world. AUVs will provide a means of obtaining data that would be otherwise unavailable except by exposing divers, mammals, and other operators to unacceptable risks. AUVs provide the mission commander in the forward area with a choice far more palatable than sending men into a suspected minefield.

However, effectively integrating AUVs into the Navy requires addressing the needs of the fleet in an end to end manner: from procurement to training, mission planning, and operations, and afterwards, data

dissemination. In recent years, REMUS has demonstrated that it is a reliable and cost effective platform for performing science based missions. In February 1998, at NAB, Coronado, REMUS demonstrated that these same capabilities would make it an effective platform for military needs. Building on these capabilities and converting them to a military application is the objective of this research. These improvements will make REMUS a highly effective tool, enabling forward mission commanders rapid assessment of beach front areas, and providing them information, options, and opportunities in a timely manner that would otherwise be unavailable.

In summary, our specific objectives are to:

Develop and demonstrate a multiple AUV navigation and target re-acquisition package. The ability to operate multiple vehicles simultaneously will provide a simple and effective means of increasing search rates and area coverage. Improved navigation techniques will also permit remote tracking of vehicles and divers, and more rapid target re-acquisition, due to the inter-operability of relative navigation systems between different diver units and different AUVs.

Establish an acoustic telemetry capability. In cooperation with the Advanced Engineering Laboratory at WHOI, the utility acoustic modem will be integrated into a REMUS test vehicle, evaluated, and then integrated into vehicles under development for NAVSEA PMS 325J. This capability will also be integrated into the remote tracking system, permitting bi-directional communication with the vehicle from remote locations via a surface buoy and an acoustic modem.

Develop compact and low power multi-beam planar array technology. The acoustic Doppler Velocity log and current meter has proven itself a valuable sensor augmenting AUV navigation. WHOI is collaborating with RD Instruments, Inc. of San Diego, CA, in the development of the next generation of Doppler Velocity Sensors (DVS), based on recent advances in multi-beam transducer and DSP technology. This task will develop reduced size electronics, permitting the delivery of a new DVS for REMUS, which is half the length and weight of the existing system, by the 4th quarter of FY 99. During FY 2000, the length and weight of this sensor will be cut in half again by using new phased array transducers. This sensor will also be integrated into a REMUS vehicle and tested.

Develop an optical imaging and payload delivery package. WHOI will develop a payload delivery module for the subsurface deployment of bottom mounted instrumentation, such as a navigation transponder. In addition, an optical imaging sensor system will be developed, based on high-resolution electronic still imaging technology, for bottom classification and target imaging. Maneuvering tactics that are required for using this technology in mine identification will also be investigated.

Develop data compilation and forwarding capabilities. To successfully complete a VSW MCM mission, the data collected must be compiled and forwarded to the task force commander. WHOI will develop an automated system that interfaces AUV mission planning and data transfer into defined DOD formats and software systems.

Support the development of Computer-Aided Detection and Classification (CAD/CAC) capability. WHOI will provide side scan sonar imagery with navigation data to CAD/CAC developers for processing on their systems. WHOI will assist these contractors in understanding file formats and in the overall evaluation of the performance of these systems. The out-year goal is the integration of CAD/CAC technology into the vehicle or system.

Field Evaluations. Annual field evaluation trips are planned to test and demonstrate the progress on each of the major tasks, and to continue to obtain feedback from fleet personnel regarding the VSW MCM problems.

APPROACH

Field evaluations sponsored by ONR and PMS 325J have established that a REMUS vehicle system could provide the Initial Operational Capability (IOC) required supporting the VSW MCM needs of SPECWAR. An ongoing program sponsored by ONR and PMS 325J will establish this IOC. This research addresses a number of deficiencies that are identified in ANNEX A of the Capstone Requirements Document for Very Shallow Water Mine Countermeasures and Hydrographic Reconnaissance. As these improvements are developed, they will become available for integration into the SARHV system.

A number of improvements, which may be incorporated into existing vehicles over the course of this program, will be developed. Each of these improvements will be field tested and validated through interactions with ONR, the VSW Detachment, and NAVSEA PMS 325J. In all cases, the improvements will strive to insure inter-operability with other VSW MCM/HR assets.

This research is being performed by Christopher von Alt and Thomas Austin, who are the co-principal investigators. Roger Stokey is developing vehicle software for the control system, and data compilation and forwarding. Lee Freitag is playing a key role in the acoustic modem effort. Mike Purcell and Robert Goldsborough are developing the payload delivery and optical imaging package. The improvements to the RD Instruments DVL are supported by Joel Young at RDI.. Gerald Dobeck of CSS supports the CAD/CAC effort and interfaces with other participants.

WORK COMPLETED

Multiple AUV Navigation and Target Re-Acquisition. The primary focus of this task is inter-operability between the SAHRV vehicles, other AUVs and divers. Meetings have been held with members from Florida Atlantic University, Perry Technologies, ARL-UT, PMS 325J, and PMS-EOD. These meetings have focused on establishing requirements for a multi-AUV, multi-diver navigation and target re-acquisition package. The package will consist of spread spectrum acoustic beacons that operate in either transponder or synchronous transmission modes. The beacons will be compatible with other AUVs as well as diver operated units. The beacons will be designed to support operations at frequencies from 10 to 30 kHz.

Acoustic Telemetry. A WHOI utility acoustic modem and an Ocean Sensors 2000 CTD have been integrated into an existing REMUS vehicle. Testing of this complete system has occurred in the waters surrounding Woods Hole in October. The system will be operated in near shore areas off Gulf Port, Mississippi during the ONR/NAVOCEANO AUV Fest in November. During these tests, the modem operating on REMUS will transmit to a multi-channel array operating from the R/V Gyre. This set up will be used to establish the temporal and geo-spatial characteristics of the near shore acoustic channel in various locations. Different spread spectrum communication codes will be tested

In addition, the Advance Development Model (ADM) SAHRV vehicle, which has been developed under separate funding, has been designed to permit the integration of the modem with little additional modification. This capability will permit the integration of this technology in SAHRV as required.

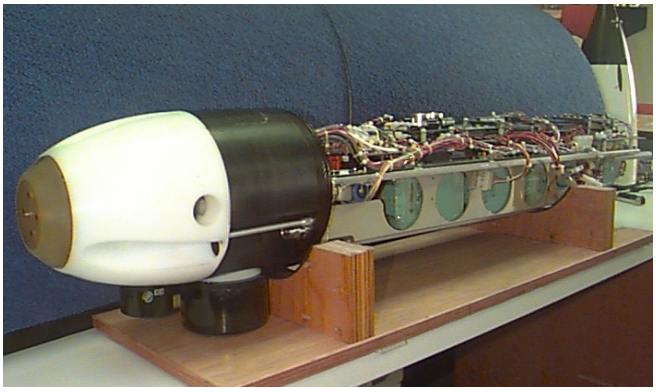

Figure 2. REMUS with 10 kHz transducer

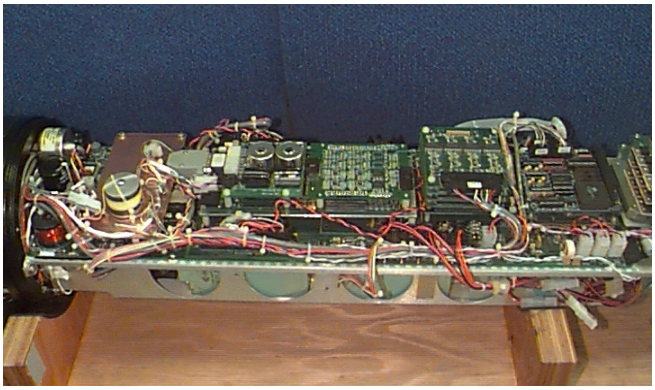

Figure 3. Modem installed in REMUS

Multi-Beam Planar Array Technology. A contract has been let to RDI Instruments to develop a multi-beam planar array for the REMUS vehicle. This array will be 4 inches long and provide both up looking and down looking capabilities. As part of this development, RDI was to develop a six-inch long, down looking only DVL for REMUS. This instrument has been developed and integrated into the SAHRV ADM vehicles. The instrument was tested at NAB in Coronado, CA in October. A second, half-length up/down instrument will be delivered in mid December. Work is in progress on developing a 600 kHz phased array sonar and associated electronics. Ceramics for the new phased array have been placed on order. The design of the electronics is in process. Development of the firmware, which is the most challenging part of the program, will begin after the hardware has been built.

Data Compilation and Forwarding. The interface to Special Warfare Automated Mission Planning Software (SWAMPS) is under development. We have met with Jerry Moy of California Microwave Systems, the developers of SWAMPS. They are developing an interface specification. No problems interfacing with this system are expected.

Efforts to format hydrographic data by REMUS to a NIMA standard vector product format are underway with no anticipated problems. Efforts to convert hydrographic data to the National Imagery Data format have not begun; however, significant research has been conducted. Methods that will be used to overlay data onto a Controlled Image Base (CIB) are currently under investigation.

Computer Aided Detection and Classification (CAD/CAC). A number of CD-ROMs, containing side scan sonar files and other information of interest, were prepared and delivered to the Coastal System Station in Panama City, FL in May. The CD-ROM contains information from side scan surveys performed with REMUS. Additional side scan data will be provided in November. This data will be collected during the PMS 325J sponsored evaluation of the SAHRV vehicle and during the AUV Fest.

Field Evaluations. Representatives from WHOI attended a joint planning meeting for Fleet Battle Experiment Hotel sponsored by ONR in September. Initial demonstrations of the SARHV vehicle are planned for August or September of 2000. Initial operations and testing of the acoustic modem took place at the ONR/NAVOCEANO AUV Fest in Gulf Port, Mississippi during November 1999.

RESULTS

A preliminary design for the multiple AUV navigation and re-acquisition package has been developed. A series of meetings will be held in late November and early December that will finalize the design of the

system. Board level designs and equipment fabrication will be completed during the second quarter, permitting delivery of initial units by April. These units will be used in the ADM II vehicles and in the CETUS vehicle during Fleet Battle Experiment Hotel, which is scheduled for August –September 2000.

The WHOI acoustic utility modem has been integrated into an existing REMUS vehicle. The SAHRV vehicle has been designed so that it can utilize this modem. The modem has been tested in local waters near WHOI, and will be demonstrated at the AUV Fest in November 1999.

The new half-length RD DVL has been developed and integrated into the SAHRV. This first planned product improvement has been transitioned into the NAVSEA PMS 32J acquisition program.

Testing of CAD/CAC software on sonar images collected by REMUS has progressed. Initial efforts indicate that there is a strong possibility that this software can be used to simplify the post processing of sonar records collected in the field by SAHRV. An extensive data set of mines in shallow water was collected by the new SAHRV ADM vehicles during November. These data will be made available to the CAD/CAC team in early December.

IMPACT/APPLICATIONS

The United States Special Operations Command in Tampa, FL has approved an Operational Requirements Document (ORD), which describes a need for a very shallow water mine countermeasure and a semi-autonomous hydrographic reconnaissance system. This document details a system which is essentially identical to the technology which has been developed at WHOI and states that no change in the Naval Special Warfare force structure will be required to support this technology. The ORD also establishes that a full operational capability will be achieved when a complete inventory of 28 vehicles with full logistic support and training is in place. Currently, full operational capability is called for in FY01. It is anticipated that the results of this research will be transitioned into the SAHRV system in the future.

TRANSITIONS

An objective of this proposal is to provide NSW teams with an Initial Operating Capability (equipment and training) to conduct shallow water minefield and hydrographic reconnaissance with small autonomous underwater vehicles by FY01. It is anticipated that the results of this research will be incorporated into the SAHRV system sometime in FY02 or 03.

RELATED PROJECTS

1. Semi-Autonomous Hydrographic Reconnaissance Vehicle; PMS 325J

2. Diver and AUV Systems and Technologies for VSW/SZ MCM Missions

3. Autonomous Platform Systems for VSW/SZ MCM

PUBLICATIONS

Stokey, R., Austin, T., von Alt, C., Purcell, M., Goldsborough, R. Forrester, N., Allen, B., 1999: "AUV Bloopers, or Why Murphy Must Have Been an Optimist: A Practical Look at Achieving Mission Level Reliability in an Autonomous Underwater Vehicle", *Proceedings of the 11th International Symposium on Unmanned, Untethered, Submersible Technology*, August 23-25, pages 32-40.

Stokey, R.T., Austin, T., 1999: "Sequential, Long Base Line Navigation for REMUS, an Autonomous Underwater Vehicle", Information Systems for Navy Divers and Autonomous Underwater Vehicles Operating in Very Shallow Water and Surf Zone Regions, April, pp 212-219.